Embedded Networks

Local Interconnect Network

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What is LIN?

- LIN: Local Interconnect Network
- It is a serial communications protocol which efficiently supports the control of mechatronic nodes in distributed automotive applications.
- The domain is class-A multiplex buses with a single master node and a set of slave nodes

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LIN Features

- The main properties of the LIN bus are:
  1. Single-master / multiple-slave concept
  2. Low cost silicon implementation based on common UART/SCI interface
  3. Hardware, an equivalent in software, or as pure state machine.
  4. Self synchronization without quartz or ceramics resonator in the slave nodes
  5. Deterministic signal transmission
  6. Low cost single-wire implementation
  7. Speed up to 20kbit/s

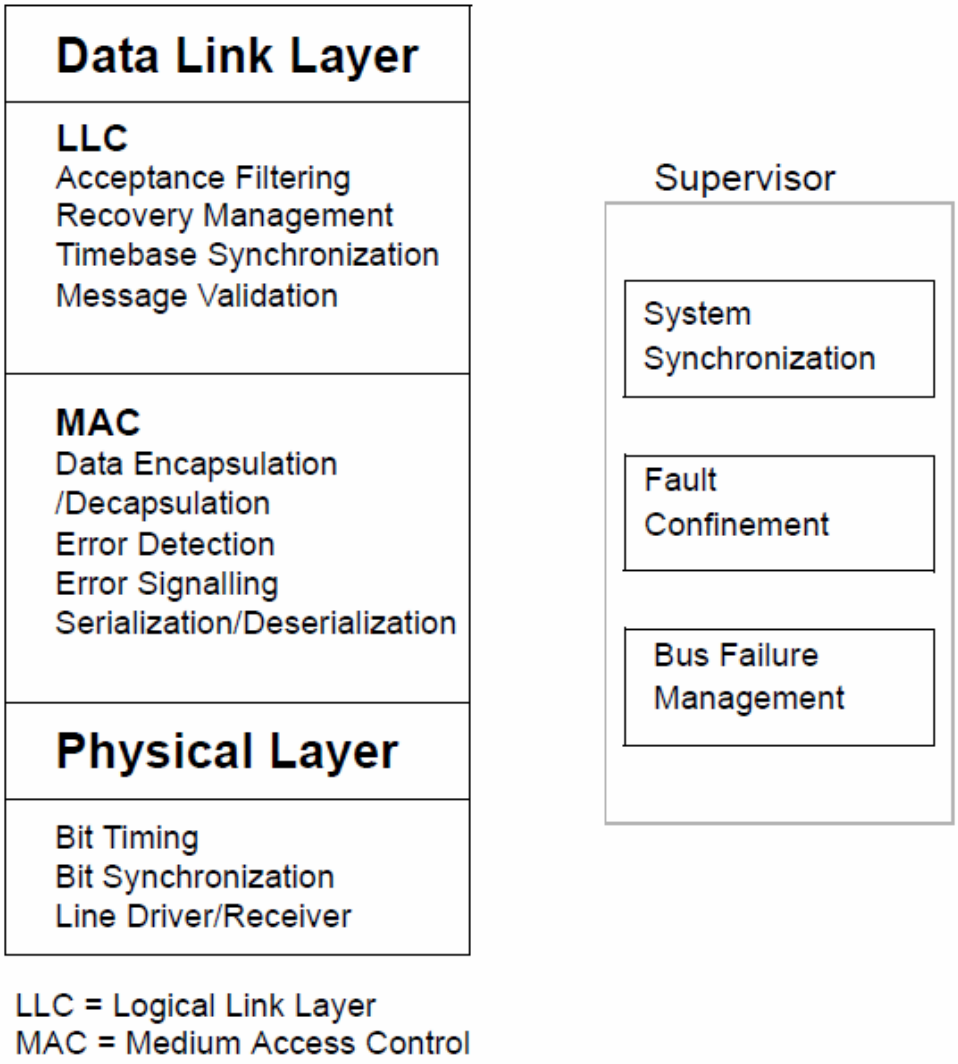
Why LIN?

- Low Cost (Almost $1 per node)
- Half the price of CAN
- Baud Rate much slower than CAN networks.
- Self synchronization in the slave nodes without crystal or ceramics resonator
- Mainly used for lower demanding applications such as side view mirrors, seats, sensors, actuators, etc.
- Cuts on development costs.
- Implementation based on common UART/SCI interface hardware

LIN Versions

- 1.2 , 1.3 , 2.0 and the new 2.1
- Most Products are developed using LIN version 1.3 because it’s ease of use and simplicity. Nowadays, LIN 2.0 is becoming more accepted among Automotive developers.
- 2.0 or 2.1 versions are recommended for new designs.
- 1.3 slaves will works in 2.0 systems, but won't work from 2.0 slaves to 1.3 systems.

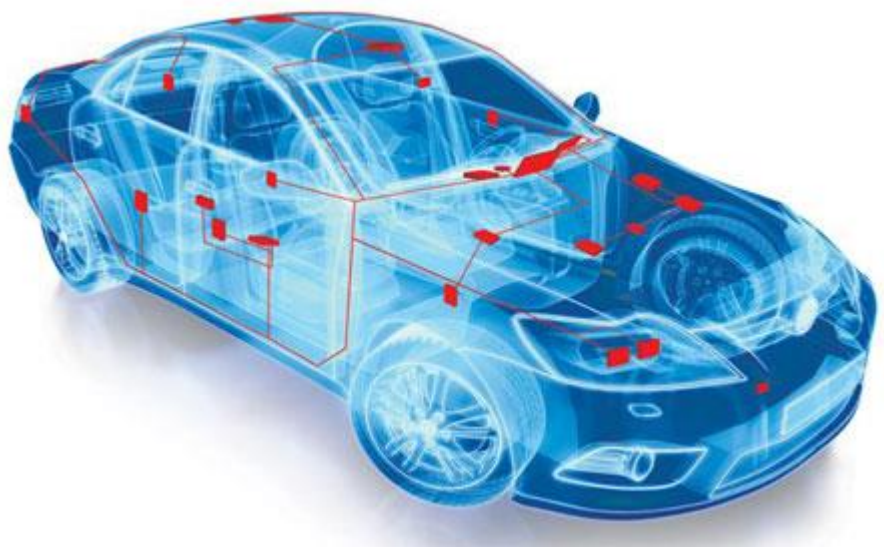
LIN and the OSI Model



LLC = Logical Link Layer
MAC = Medium Access Control

Applications

- The LIN protocol was suggested in 1999 as a low cost sub-bus system to complement CAN in applications such as:
  - Vehicle Roof (Rain Sensor, Light Sensor, Light Control, Sun Roof)
  - Vehicle Doors (Mirror, Central Locking, Mirror Switch, Window Lift)
  - Engine (Sensors, Small Motors, Steering Wheel, Cruise Control Switches, Wiper, Turn Signal, Radio, Climate Control)
  - Seat (Seat Position Motors, Seat heater, Occupancy Sensor)



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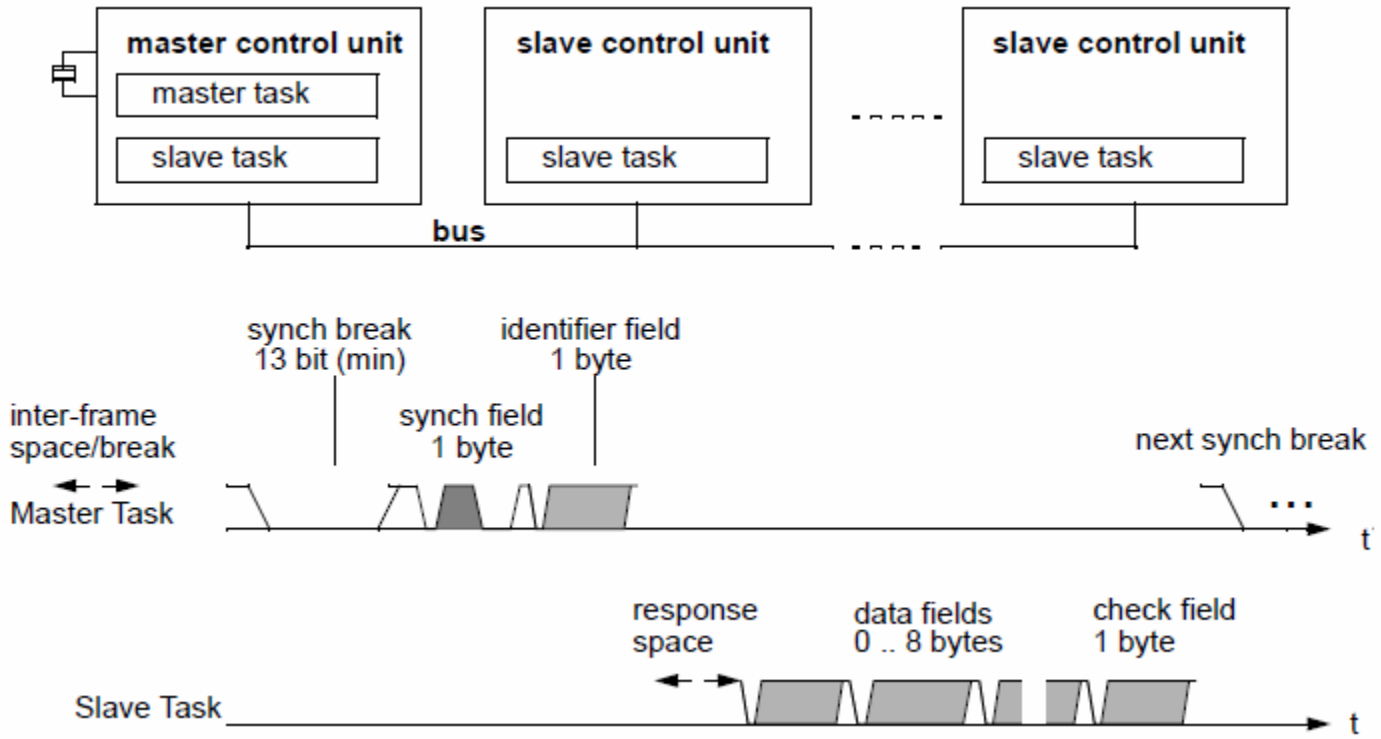
Master / Slave Protocol

- Master Task
  - Determines order and priority of messages.
  - Monitors Data and check byte and controls the error handler.
  - Serves as a reference with its clock base (stable clock necessary)
  - Receives Wake- Up Break from slave nodes
- Slave Task
  - Is one of 2-16 members on the bus
  - Receives or transmits data when an appropriate ID is sent by the master.
  - The node serving as a master can be slave, too!

Communication Concept



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Information Routing

- In LIN systems a node does not make use of any information about the system configuration, except for the denomination of the single master node.
  - System Flexibility: Nodes can be added to the LIN network without requiring hardware or software changes in other slave nodes.
  - Message routing: The content of a message is named by an IDENTIFIER. The IDENTIFIER does not indicate the destination of the message, but describes the meaning of the data. The maximum number of identifier is 64, out of which 4 are reserved for special communication purposes such as software upgrades or diagnostics.
  - Multicast: As a consequence of the Message Filtering any number of nodes can simultaneously receive and act upon messages.

Bit Rate

- The maximum bit rate is 20kbit/s, given by the EMI limitation of the single wire transmission medium. The minimum bit rate is 1kbit/s to avoid conflicts with the practical implementation of time-out periods.
- In order to allow implementation of low cost LIN devices, the use of following bit-rates is recommended

Slow	Medium	Fast
2400 bits/sec	9600 bits/sec	19200 bits/sec

Master / Slave Protocol

- Master
  - Has control over the whole Bus and Protocol
  - The master controls which message at what time is to be transferred over the bus. It also does the error handling. To accomplish this the master
    - Sends Sync Break
    - Sends Sync Byte
    - Sends ID-Field
    - Monitors Data Bytes and Check Byte, and evaluates them on consistence
    - Receives WakeUp Break from slave nodes when the bus is inactive and they request some action.
    - Serves as a reference with it’s clock base (stable clock necessary)

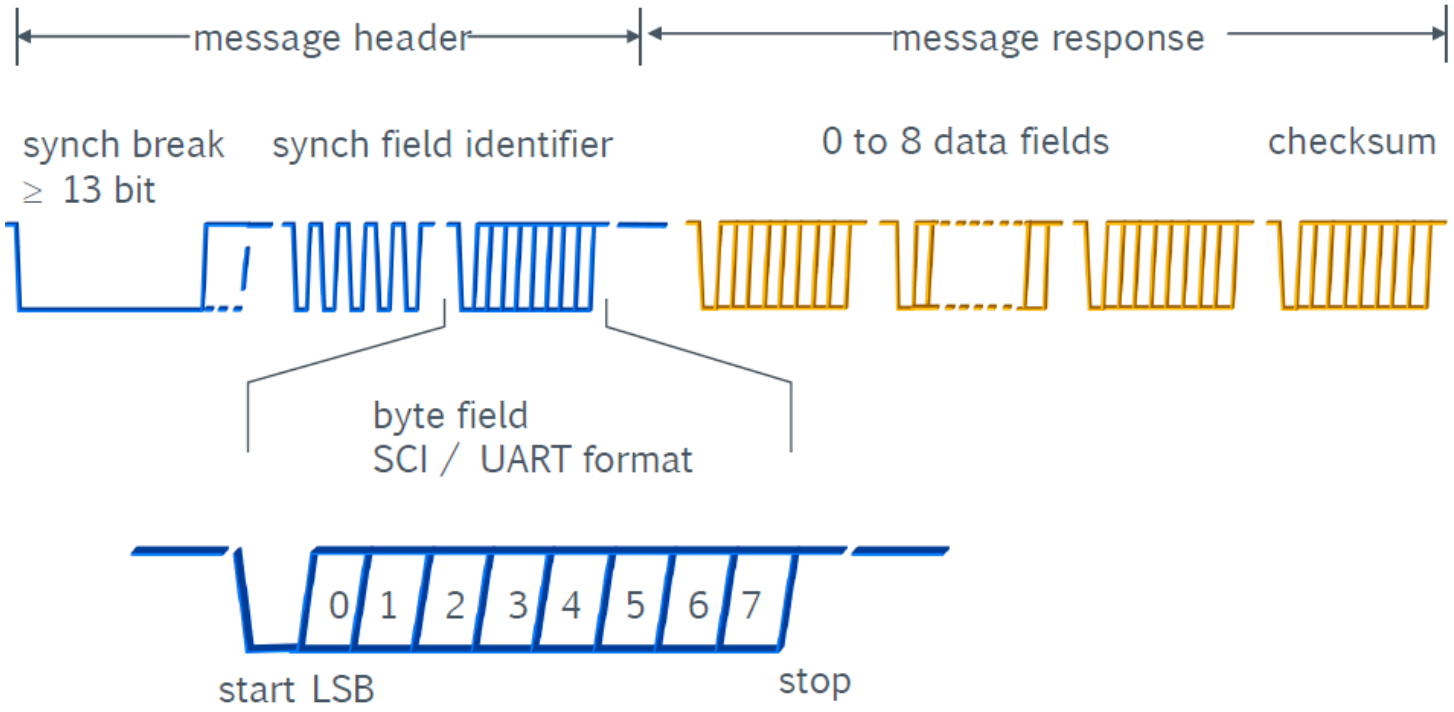
Master / Slave Protocol

- Slave
  - Is one of 2-16 Members on the Bus and receives or transmits Data when an appropriate ID is sent by the master.
    - Slave snoops for ID.
  - According to ID, slave determines what to do.
    - either receive data
    - or transmit data
    - or do nothing.
  - When transmitting the slave
    - sends 1, 2, 4, or 8 Data Bytes
    - sends Check-Byte
  - The node serving as a master can be slave, too!

Local Interconnect Network

Frame Format

LIN Frame Format



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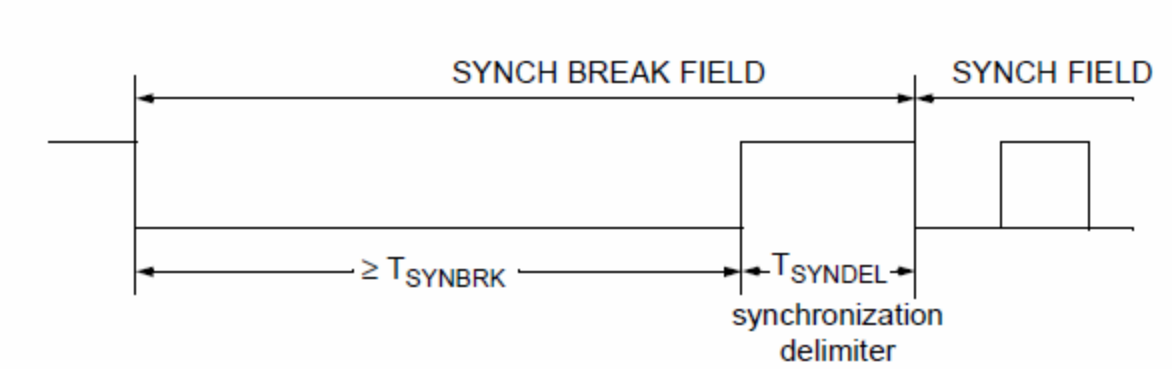
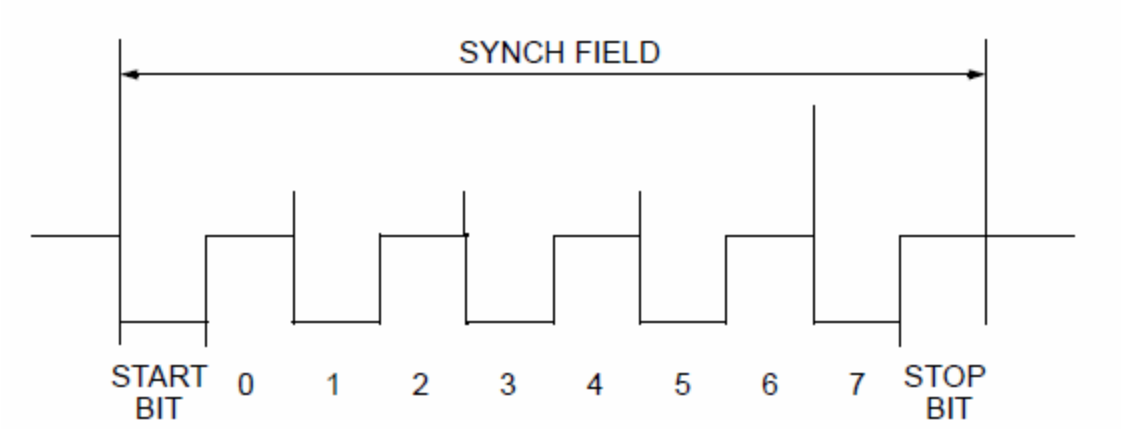
Frame Format - Header

- Synch Break:
  - In order to identify clearly a beginning of a message frame it's first field is a synchronization break (SYNCH BREAK). A SYNCH BREAK FIELD is always sent by the master task.



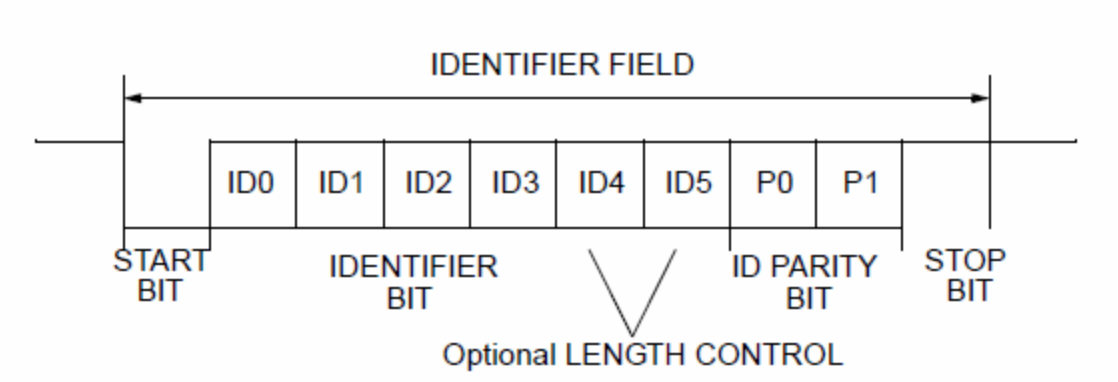
Frame Format - Header

- Synch Byte:
  - Specific Pattern for Determination of Time Base (Determination of the time between two rising edges)
  - A Synch Byte precedes any Message Frame



Frame Format - Header

- Identifier-Field:
  - Message Identifier: Incorporates Information about the sender, the receiver(s), the purpose, and the Data field length. Length 6 Bit. 4 classes of 1/2/4/8 Data Bytes. The length coding is in the 2 LSB of the ID-Field. Each class has 16 Identifiers. A total of 64 Message Identifiers are possible.
  - 2 Parity Bits protect this highly sensitive ID-Field.



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Frame Format - Header

- 2 Parity Bits protect this highly sensitive ID-Field.

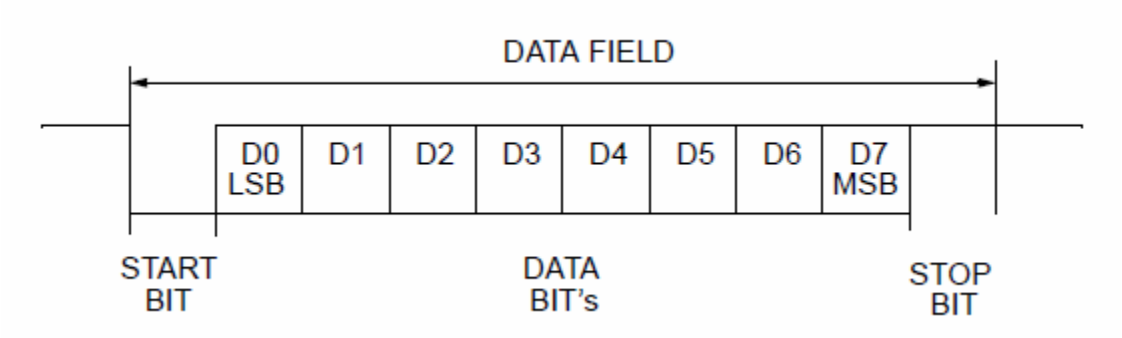
The parity check bits of the identifier are calculated by a mixed-parity algorithm:

Equation 3.1.1:	$P0 = ID0 \oplus ID1 \oplus ID2 \oplus ID4$	(even parity)
Equation 3.1.2:	$P1 = \overline{ID1 \oplus ID3 \oplus ID4 \oplus ID5}$	(odd parity)

- The identifiers 0x3C, 0x3D, 0x3E, and 0x3F with their respective IDENTIFIER FIELDS 0x3C, 0x7D, 0xFE, and 0xBF (all 8-byte messages) are reserved for command frames(e.g. sleep mode) and extended frames.

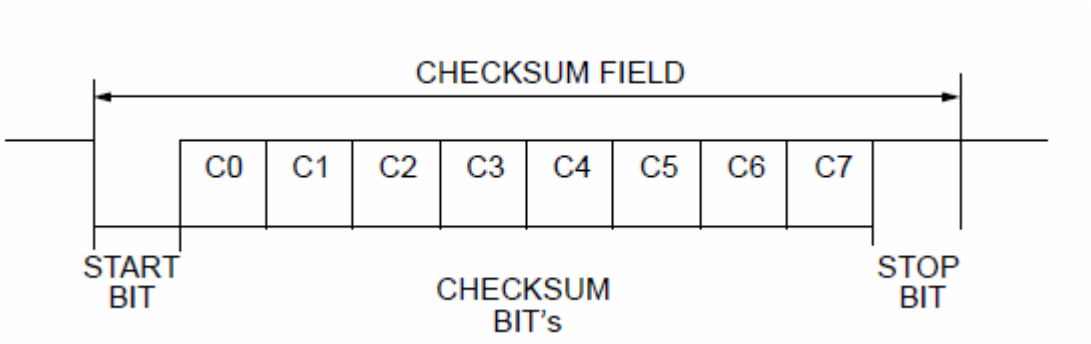
Frame Format - Response

- The DATA FIELD consists of a BYTE FIELD containing eight bits of data to be transferred by a MESSAGE FRAME. The transmission happens LSB first.



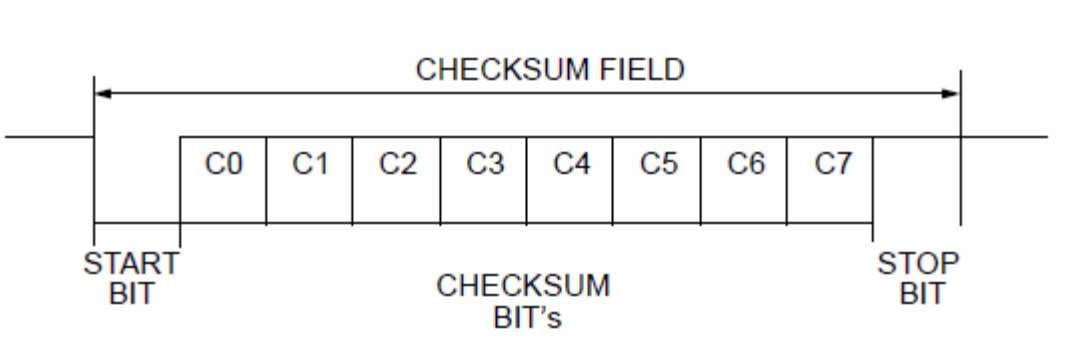
Frame Format - Response

- The CHECKSUM FIELD (LIN 1.3) contains the inverted modulo-256 sum over all data bytes
- The sum is calculated by “ADD with Carry” where the carry bit of each addition is added to the LSB of it’s resulting sum. This guarantees security also for the MSBs of the data bytes.



Frame Format - Response

- The CHECKSUM FIELD (LIN 2.0) contains the inverted modulo-256 sum over all data bytes and the protected identifier
- The sum is calculated by “ADD with Carry” where the carry bit of each addition is added to the LSB of it’s resulting sum. This guarantees security also for the MSBs of the data bytes.



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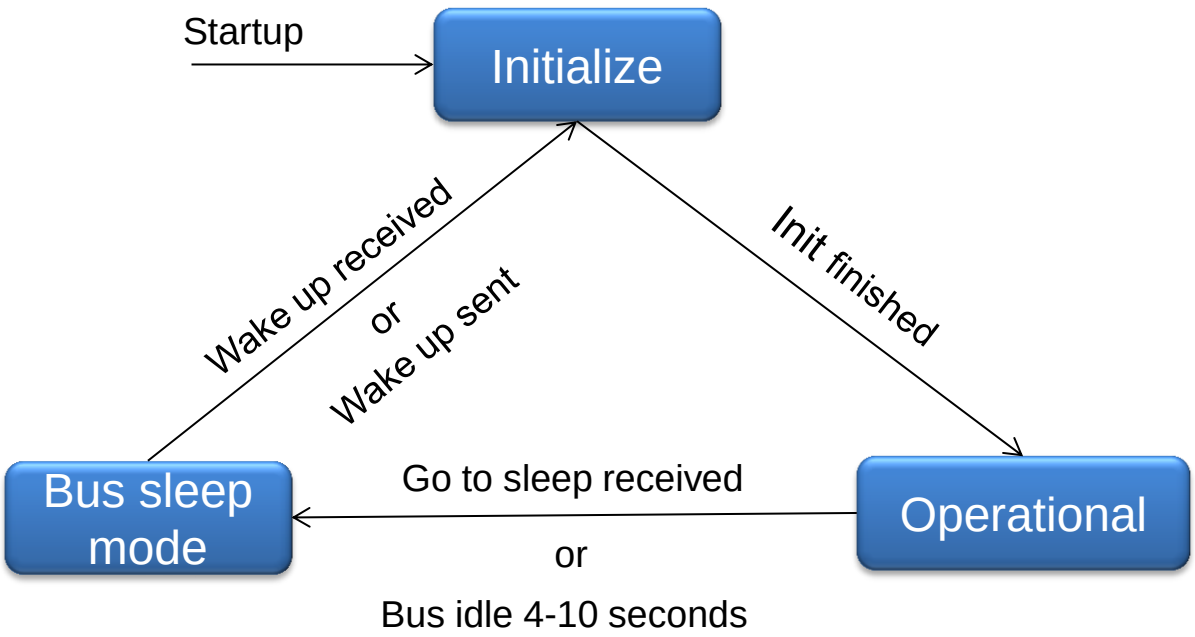
Network Management

Network Management

- Wake-Up and Go-To-Sleep
- Slave communication sate diagram

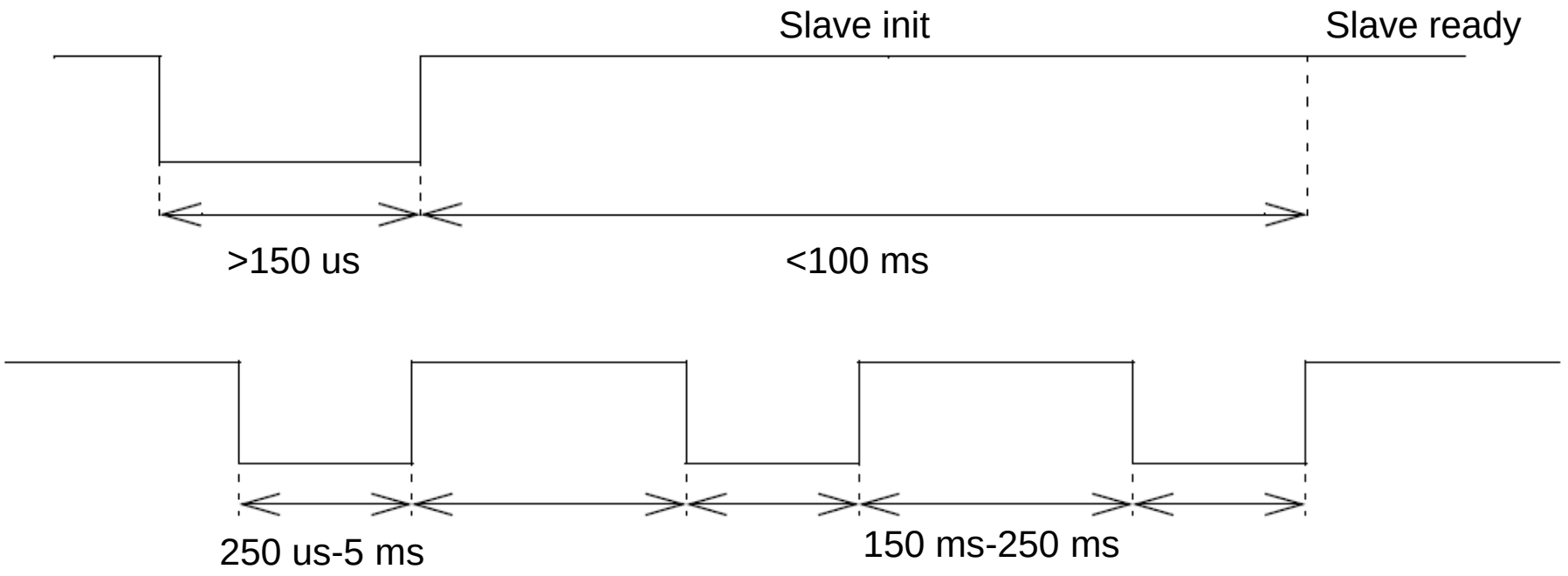


Network Management

- Wake-Up LIN 2.0
  - Any node in a sleeping LIN cluster may request a wake up.
  - The wake-up request is issued by forcing the bus to the dominant state for 250 µs to 5 ms.
  - Every slave node (connected to power)
    - shall detect the wake-up request (a dominant pulse longer than 150 µs)
    - and be ready to listen to bus commands within 100 ms.
  - If the master does not issue frame headers within 150 ms from the wake up request,
    - the node issuing the request may try issuing a new wake up request
    - after three (failing) requests the node shall wait minimum 1.5 seconds before issuing a fourth wake up request.

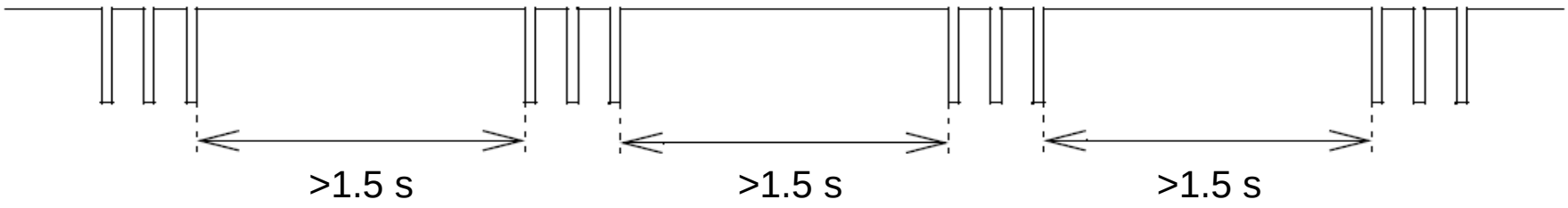
Network Management

- Wake-Up
  - Force the bus to dominant state for 250us to 5ms
  - Can be sent by any LIN node



Network Management

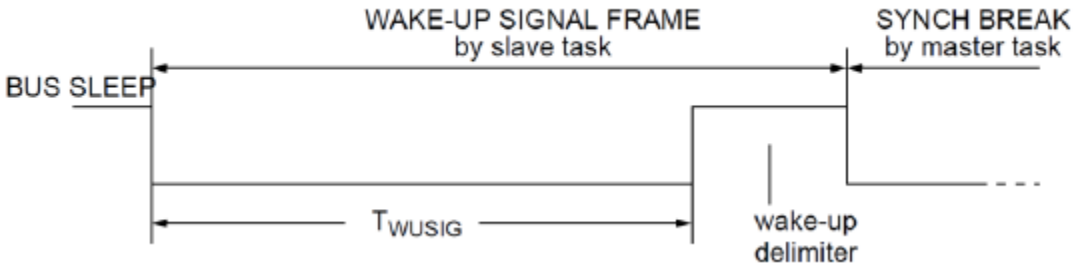
- After 3 failing wake up requests: minimum 1.5s wait time



Wake-Up LIN 1.3

Wake-up	Logical	Name	Min [Tbit]	Nom[Tbit]	Max[Tbit]
Wake up signal	Dominant	T_{wusig}		8^a	
Wake up signal delimiter	Recessive	T_{wudel}	4		64
Timeout after wake up signal	Recessive	T_{tobrk}			128
Timeout after three breaks	Recessive	T_{t3brk}	15000		

Note a: This bit time is based on the respective Slave Clock



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Network Management

- Go-to-Sleep LIN 1.3/2.0
  - All slave nodes in an active cluster can be forced into sleep mode by sending a diagnostic master request frame (frame identifier = 0x3c) with the first data byte equal to zero.
  - This special use of a diagnostic frame is called a go-to-sleep-command
  - Slave nodes shall also automatically enter a sleep mode if the LIN bus is inactive13 for more than 4 seconds*

  *note: timing only applies to LIN 2.0

  - Done by:
    - Master request frame

0x00	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

    - Bus idle 4-10 seconds

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Timing of a message Frame. LIN 1.3

Time	Name	Time[Tbit]
Minimum Length of Message Frame	T_{frame_min}	$10 * N_{data} + 44$
Minimum Length of Header	T_{header_min}	34
Maximum Length of Header	T_{header_max}	$T_{header\_min} * 1.4$
Maximum Length of Message Frame	T_{frame_max}	$T_{frame\_min} * 1.4$
Bus Idle Time-Out	T_{time_out}	25000

Timing of a message Frame. LIN 2.0

Time	Name	Time[Tbit]
Minimum Length of Message Frame	T_{frame_min}	$10 * N_{data} + 44$
Minimum Length of Header	T_{header_min}	34
Maximum Length of Header	T_{header_max}	$T_{header\_min} * 1.4$
Maximum Length of Message Frame	T_{frame_max}	$T_{frame\_min} * 1.4$
Bus Idle Time-Out	T_{time_out}	4 seconds

Local Interconnect Network

Types of Frames

Command Frames

- Are used to broadcast general command requests for service purposes from the master to all bus participants:
  - ID = 0x3C(0x3C) “Master request frame” to send commands and data from the master to the slave node
  - ID = 0x3D(0x7F) “Slave response frame” that triggers one node to send data to the master node
- first data byte of a command frame containing the values from 0x00 to 0x7F are reserved:
  - SLEEP MODE command - used to broadcast the sleep mode to all bus nodes
  - ID = 0x3C and DATA(0)=0x00

Extended Frames

- Are reserved to allow the embedding of user-defined message formats and future LIN formats into LIN protocol without violating the current LIN specification:
  - ID = 0x3E(0xFE) user defined extended frame
  - ID = 0x3F(0xBF) future LIN extension
- the identifier can be followed by an arbitrary number of LIN bytes field

Local Interconnect Network

Error and Exception Handling

Error and Exception Handling

- Types of Errors
  - Bit-Error
  - Checksum error
  - Identifier-Parity-Error
  - Slave-Not-Responding-Error
  - Inconsistent-Synch-Field-Error
  - Physical-Bus-Error

Bit Error

- Error description
  - The bit actually appearing on the bus is different that the one transmitted

- Method of detection
  - Sending unit monitors the bus while transmitting. A BIT_ERROR has to be detected at that bit time.

- Fault Confinement

  This error is detected by
  - master task in master
  - slave task in slave

  while reading back its own transmission

Checksum Error

- Error description
  - The inverted modulo-256 sum over all received data bytes does not match with the receive checksum byte
- Method of detection
  - The sum of the inverted modulo-256 sum over all received data bytes and the checksum byte does not result in 0xFF
- Fault Confinement

  This error is detected by
  - slave task in master when expecting or reading data from the bus
  - slave task in slave while reading from the bus

Identifier-Parity Error

- Error description
  - The parity identifier bits does not match with the correct calculated values
- Method of detection
  - Typical LIN slave application do not distinguish between an unknown but valid identifier and a corrupted identifier
- Fault Confinement

  This error is detected by
  - master task in master while reading back its own transmission
  - slave task in slave while reading from the bus

Slave-Not-Responding Error

- Error description
  - The message frame is not fully completed within the maximum frame length
- Method of detection
  - A slave task waits the entire message upon transmission of the new header
- Fault Confinement

  This error is detected by
  - slave task in master when expecting or reading data from the bus
  - slave task in slave while reading from the bus only when a slave expects a message from another slave

Inconsistent-Synch-Field Error

- Error description
  - Synch field is different than the pattern 0x55
- Method of detection
  - Slave task detects edges of Synch field outside the given tolerance
- Fault Confinement

  This error is detected by only by slave task in slave

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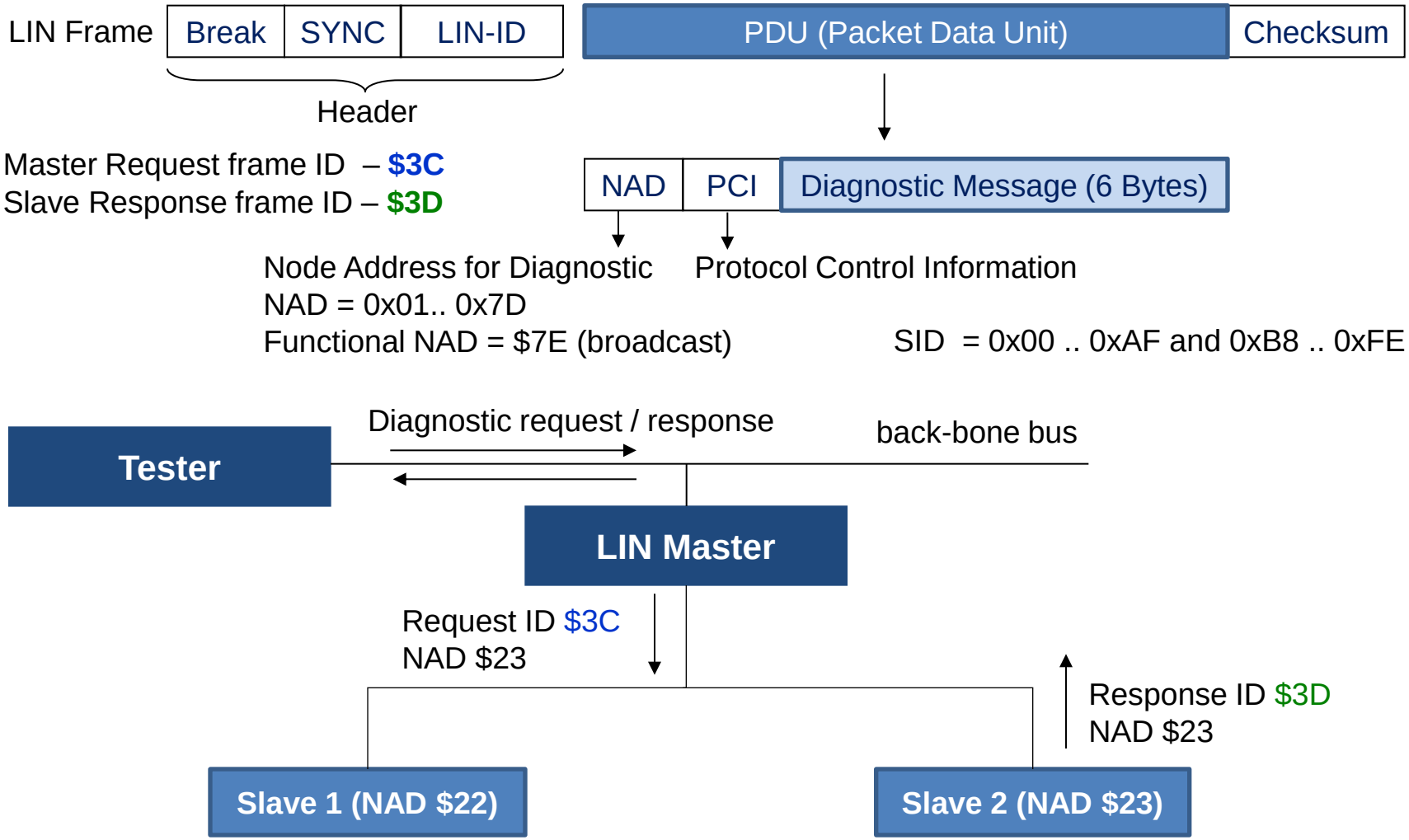
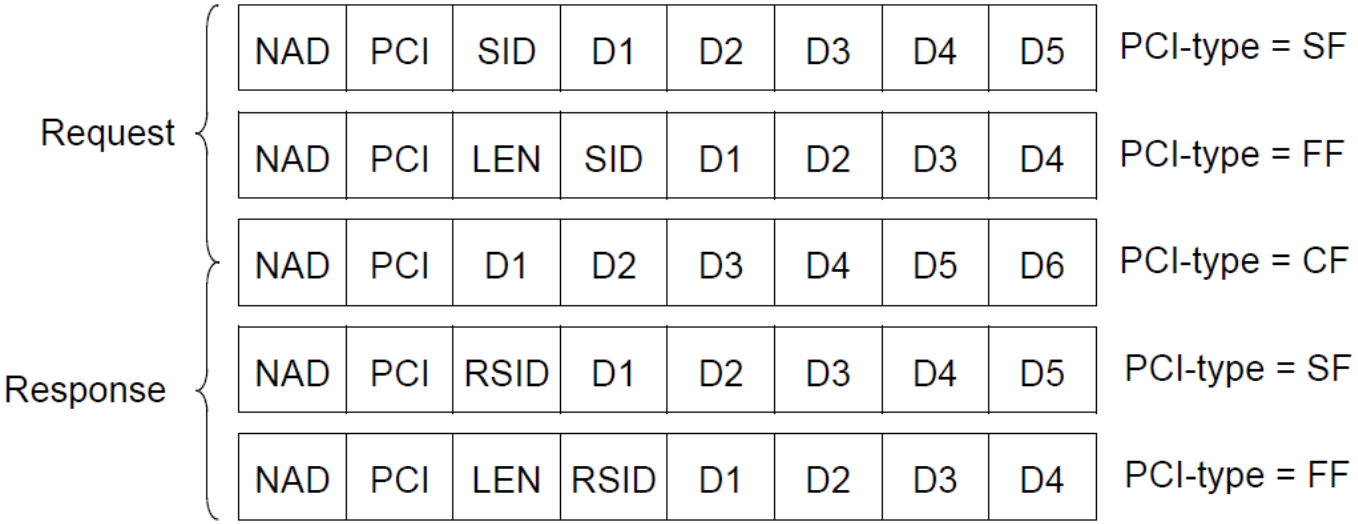
Transport Layer – Diagnostics Communication

Transport Layer



Transport Layer – Protocol Control Information

- PDU's supported by the LIN transport layer



- Structure of the PCI byte

Type	PCI type				Additional information			
	B7	B6	B5	B4	B3	B2	B1	B0
SF	0	0	0	0	Length			
FF	0	0	0	1	Length/256			
CF	0	0	1	0	Frame counter			

Transport Layer